

Problematic Use of Energy Drinks by Adolescents

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KEYWORDS

- Adolescents • College students • Energy drinks
- Caffeine • Alcohol • High-risk behaviors

Since the introduction of the energy drink (ED) Red Bull in 1987 to Europe and in the 1990s to the United States, the popularity of EDs has increased, particularly with the youth population. In 2008, annual sales of EDs accounted for \$3.2 billion in the United States and \$7.8 billion worldwide.¹ To appeal to adolescents and young adults, many EDs carry names that have clear marketing reference to psychoactive drug use such as Cocaine and Blow, whereas others have names that glamorize antisocial behavior like Pimp Juice and Venom. These beverages have been marketed as legal alternatives to gain status as cool beverages. An article with the catchy title A Can of Bull? represents a line of publications questioning the pivotal claim that EDs provide a source of physical and mental energy.² Given the popularity of EDs it is surprising that limited literature is available.

This article reviews the literature on EDs and examines their problematic use and the potential negative consequences that these drinks have on young people. Special emphasis is devoted to safety concerns regarding the combination of EDs with alcohol, whether as a commercially packaged beverage or as a mix tailored by the consumer.

THE COMPOSITION OF EDS

The 2 main ingredients in EDs are caffeine and sugar/carbohydrates. In addition, the natural products found in most EDs include several of the following: guarana, B complex vitamins, ginseng, amino acids (eg, taurine), gluconolactone, niacin, inositol, pantenol, and bitter orange. Bitter orange contains synephrine, a newly popular alternative to ephedrine. Ephedrine is the active ingredient in ephedra, once included in some diet and performance-enhancing drinks. The US Food and Drug Administration (FDA), banned ephedra in 2004 after it was linked to heart problems and approximately 80 heatstroke deaths among young athletes.³ The main stimulating effects of

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EDs have been attributed to caffeine as well as to the rush caused by the combination of caffeine and the high dosage of carbohydrates and sugar found in most beverages.

The content of caffeine in EDs varies from 116 mg in the leading brand Red Bull to 428 mg in Spike Shooter. In comparison, a cup of coffee contains 75 mg of caffeine and Coca-Cola Classic/Mountain Dew contains 23 mg. In addition, approximately 50 g of sugar/carbohydrates per serving are commonly present in EDs. All comparisons are in reference to a 340-g (12-oz) serving.

Several EDs do not contain carbohydrates and are therefore marketed as low-calorie energy beverages that charge the user at a cellular level. ACT Energy contains Stevia, a natural sweetener, and maca root, which has been promoted to improve cardiovascular function and act as an antidepressant. The beverage Cocaine not only contains 280 mg of caffeine but also includes a throat-numbing confidential ingredient added to justify its name.⁴

An important example of a low-calorie energy beverage is 5-Hour Energy, which controls 80% of the market of energy shots. The 59-mL (2-fluid oz) drink contains various B vitamins and amino acids. This ED is marketed as an energy blend with an antidepressant property due to phenylalanine⁵ (<http://5hourenergy.com/product.asp>). This is now the most popular category of ED, with sales expected to double from 2008 to about \$700 million. This power drink costs 20 times as much per ounce as Coca-Cola.⁶

THE EFFECTS OF EDS, AND TRUTH IN ADVERTISEMENT

It is claimed that EDs provide benefits to the user. The definition of a supplement refers to a substance that is taken to augment the diet. However, some supplements are drugs that exert an effect on a body system and might have physiologic side effects. Dietary supplements are treated as foods, as long as no drug claims are made for them.⁷ When products are marketed for therapeutic use, the FDA regulates them. EDs can be viewed historically as an extension of the market for sports drinks (SDs). For example, Gatorade replenishes carbohydrates and electrolytes. Drinking SDs is superior to water because the added flavor stimulates the athlete to consume more fluids that are crucial after extensive physical effort. This consumption is especially important in young athletes more than 12 years of age who dehydrate more quickly and whose core temperature increases faster than in adults, thereby exposing them to increased risk for heat stroke.⁸ SDs can be produced noncommercially by simply mixing sugar, salt, orange juice, lemon juice, and water.⁹ EDs take the market a step further by adding stimulants.

There is no legal age limit to purchasing EDs. About 30% of 12 to 17 year olds admit to regular use of EDs. High school athletes frequently use supplements, vitamins, minerals, SDs, and EDs because of perceived short-term effects on sports performance.¹⁰ Stimulants may be the most widely used supplement by high school athletes, including caffeine and guarana, which are commonly found in EDs. As the market grows, so do concerns of combining chemical stimulation with exercise. For more information on sport performance agents among high school athletes, which is beyond the scope of this article, please refer to a comprehensive review by Gregory and Fitch.⁷

According to a study among college students,¹¹ approximately one-third of those aged 18 to 24 years consume EDs. According to students' perceptions, the main reasons for consumption include coping with insufficient sleep (67%), increasing energy (65%), and increasing fun with alcohol at parties (54%). Most users consumed

1 drink to treat most situations; however, the use of 3 or more EDs with alcohol at parties was a common practice in half of ED users.

Alford and colleagues¹² reported that the effects of Red Bull significantly improved aerobic endurance and anaerobic performance on cycle ergometers compared with control drinks. Furthermore, significant improvements in mental performance included choice reaction time, concentration, and memory (immediate recall), which reflected increased subjective alertness. A placebo-controlled study concluded that effects on cognitive performance could not be predicted from the effects of glucose and caffeine in isolation. Data suggest some degree of short-term synergy between the cognition-modulating effects of glucose and caffeine.¹³

Caffeine, the main ingredient in EDs, has been reported to have stimulating effects; however, it is debatable whether these effects are usually the result of caffeine consumption among non-heavy drinkers or to the reversal of caffeine withdrawal among chronic users who have developed tolerance to caffeine. A recent study found no effect of overnight caffeine withdrawal on mood and performance. Caffeine challenges did have the predicted effect on alertness and vigilance, with the size of the effects increasing with caffeine dose in particular on non-heavy drinkers.¹⁴

Guarana has been a central component of EDs. This fruit of a domesticated rain-forest vine is known for its caffeine content and became a soft drink in Brazil about a century ago. It has also been advertised as an aphrodisiac capable of boosting libido.

The amount of the natural products found in EDs is much less than the amounts expected to deliver therapeutic benefits or adverse events.¹⁵

EDS AND RISK-TAKING BEHAVIORS

Self-reported measures of risk-taking behaviors were positively associated with frequency of ED consumption, particularly among whites.¹⁶ Risk-taking behaviors included tobacco smoking, marijuana and illicit prescription drug use, sexual risk taking, fighting, and seat-belt omission. It is plausible that a liking for EDs is a marker for high-risk behaviors.

It has been reported that a common genetic factor is associated with caffeine, nicotine, and alcohol abuse (see the article by Meyers and Dick elsewhere in this issue for further exploration of this topic).¹⁷ Caffeine has been found to increase the reinforcing effects of nicotine and, because of increased caffeine metabolism among smokers, they consume more caffeine than nonsmokers.^{18,19}

ADVERSE EFFECTS OF EDS ATTRIBUTED TO CAFFEINE

In addition to coffee, tea, and soft drinks, caffeine can be found in over-the-counter analgesics and cold remedies, antidrowsiness pills, and weight-loss aids. Chocolate and cocoa have much lower levels of caffeine. Average caffeine intake in the United States is 200 mg/d with up to 30% of Americans consuming 500 mg or more per day. According to the *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition, Text Revision) (DSM-IV-TR),²⁰ caffeine-induced disorders include caffeine intoxication, caffeine-induced anxiety disorder, and caffeine-induced sleep disorder. Although some aspects of dependence have been reported, including tolerance and withdrawal, according to the DSM, the data are insufficient to determine abuse or dependence criteria. However, some reports indicate the potential for caffeine dependence in adolescents.^{21,22}

A growing number of reports also show caffeine intoxication from EDs. Caffeine intoxication can be clinically significant. Diagnostic criteria include 5 or more of the following signs: restlessness, nervousness, excitement, insomnia, flushed face,

diuresis, gastrointestinal disturbance, muscle twitching, rambling flow of thought and speech, tachycardia, cardiac arrhythmia, psychomotor agitation, and periods of in-exhaustibility. Reissig and colleagues²³ note that the consumption of EDs may increase the risk for caffeine overdose for several reasons, including lack of adequate labeling of the amount of caffeine, lack of warning labels advising proper use, and lack of restrictions on the sale of EDs to children and adolescents.

Although individual responses to caffeine vary, the stimulating properties in EDs can increase heart rate and blood pressure, causing palpitations that may lead to emergency-room visits. EDs have also been reported to cause dehydration and insomnia.

Caffeine withdrawal is a research diagnosis in DSM-IV-TR, defined as "A phenomenon occurring after prolonged daily use of caffeine." It is diagnosed following the abrupt cessation of, or reduction in, the use of caffeine-containing products. The main symptom is a headache and 1 or more of the following symptoms: marked fatigue or drowsiness, marked anxiety or depression, and nausea or vomiting. These symptoms cause clinically significant distress or impairment in areas of functioning. Caffeine withdrawal has been identified in children^{24,25} and adolescents,^{21,22} and aggressive marketing of EDs to these populations may increase the incidence of caffeine-induced adverse effects.²³

In a comprehensive review on caffeine as a pivotal ingredient in EDs, Reissig and colleagues²³ reported that EDs have been linked to seizures, acute mania, and stroke. A review by Clauson and colleagues¹⁵ from 1980 to 2007 documented 4 case reports of caffeine-associated deaths, as well as 4 separate cases of seizures associated with EDs.

Among college students, weekly jolt and crash episodes were experienced by 29% (with a significant dose effect), headaches by 22%, and heart palpitations by 19% of ED users.¹¹ The combination of fluid loss from sweating and the diuretic properties of caffeine can also lead to dehydration, particularly among athletes and party goers.

A significant segment of adolescents in Western societies suffer from chronic sleep deprivation due to a maturational shift in the sleep-wakefulness cycle. EDs may be implicated in sleep deficits resulting in excessive daytime sleepiness. Caffeine consumption tended to be 76% higher by those who fall asleep during day time.²⁶

It seems likely that problems with caffeine intoxication, dependence, and withdrawal will continue to grow with the increased popularity of EDs and the increase in consumption figures. Adolescents who are novice drinkers of caffeine are at greater risk for caffeine intoxication because they do not use caffeine daily, and also because EDs are served cold and therefore it is easier to consume large amounts of them compared with servings of hot coffee.

EDS AND ALCOHOL INTERACTION

The use of EDs with alcohol is an increasing public health concern. Alcoholic EDs (AEDs) are affordable, prepackaged beverages that commonly contain alcohol at concentrations up to 10%, caffeine, fruit juice, and other stimulants that are commercially available (eg, caffeinated beers such as Anheuser-Busch's B-to-the-E). AEDs are popular among club goers who also are being served AEDs mixed on the spot at the bar (eg, Red Bull and vodka). Approximately a quarter of 2 large samples of college students reported using EDs with alcohol during the last month.^{11,27} College ED users consume alcohol more frequently than nonusers. These students got drunk twice as often as those who consumed alcohol only and were far more likely to be injured, require medical treatment, or ride with an intoxicated driver.²⁷ It was also

reported that those who combine EDs and alcohol are more likely to be victims or perpetrators of aggressive sexual behavior. The effect remained even after controlling for the amount of alcohol consumed.²⁷

Caffeine use with or after alcohol consumption has been erroneously and commonly perceived as a remedy to reverse the negative effects of alcohol intoxication, such as compromised motor coordination and visual reaction time. ED use simply masks alcohol effects leading to the wide-awake-and-drunk phenomenon, as demonstrated in a laboratory experiment with humans.²⁸ The ingestion of an ED did not alter the breath alcohol concentration.

A double-blind, placebo-controlled study in female participants showed that, compared with drinkers of EDs only, drinkers of EDs and alcohol at 6% by volume showed lower post-test performance on a global score of neuropsychological status. Specifically, deficits were found in visuospatial/constructional and language performance scores.²⁹ Therefore, the combined use of caffeine and alcohol may increase the rate of alcohol-related injury. Caffeine is a diuretic, and EDs and alcohol are dehydrating. Dehydration slows the metabolism of alcohol and might increase its toxicity.

Young drivers are more accident prone than adults, particularly after alcohol consumption, because of incomplete maturation of the prefrontal cortex (see the article by Rutherford and colleagues elsewhere in this issue for further exploration of this topic). The consumption of AEDs places them at an increased risk for alcohol-related consequences and having driving-associated deficits masked by the stimulating effects of the caffeine in the AED.^{30,31}

The amino acid taurine is a common ingredient in EDs. Studies with laboratory animals showed pharmacologic interaction between alcohol and taurine affecting locomotor activity, dopamine release, and liver metabolism.^{15,28} Endogenous taurine may be an important modulator of the effects of ethanol on the nervous system; however, there are no studies reported in humans. In addition, there are no data on the interaction of alcohol and other components of EDs.

LEGAL CONCERNS

Reissig and colleagues²³ noted that the FDA approved caffeine in soft drinks and limited the maximum content to 0.02%, or 71 mg per 355 mL (12 fluid oz); moreover, the FDA requires warning labels and information on the quantity of caffeine in over-the-counter stimulants. This requirement includes the recommendation of an age limit of 12 years. In contrast, there is a concerning inconsistency in FDA regulations because more than 130 EDs now exceed 0.02% of caffeine but are not marketed with warnings or information on the amount of caffeine in the product.²³

The National Association of Attorneys General (NAAG) has requested that the FDA use its authority under the Food, Drug and Cosmetics Act to remove caffeinated alcoholic beverages from the market place unless the manufacturers empirically demonstrate their safety.³² The law places the burden of proof on the safety of beverages on the manufacturers and forbids false advertising that may create a misleading impression.³¹ Some commercially prepackaged drinks were withdrawn from the market as a result of state and federal legal action. In addition, caffeine and other additives were removed from flavored malt beverages. However, other AEDs are still available and the consumer may simply mix EDs and alcohol at will.^{30,31}

The FDA responded by announcing its plan to study concerns regarding the safety of caffeinated alcoholic beverages (ie, intoxicating EDs). There are estimates of consumption rates of 18% for college-age students.³³

RECENT DEVELOPMENT IN THE ED MARKET

There is a dynamic market for EDs that is continually expanding. This trend was illustrated by a report on CBS radio 880 in New York, in early spring of 2010, that chewable EDs will be available shortly in the form of beef jerky.

The enormous success of energy shots such as the 5-Hour Energy has forced big beverage makers to develop similar products. Dr Pepper began marketing an 85-g (3-oz) version of its Venom ED, called Venom Bite. Coca-Cola and Red Bull also introduced a shot drink.⁶

A new line of mood-altering beverages with a cannabis-oriented marketing campaign (eg, weed in a bottle) known as Anti EDs has recently appeared in the American market.^{1,34} These drinks are marketed as an alternative to alcohol or to caffeine-laced EDs by producing calming and relaxing effects without losing focus and concentration. These sugary drinks are laced with folk-medicine sedatives, such as chamomile, valerian root, the south pacific kava root, rose hips (a source of vitamin C and antioxidants derived from rose plants), and the hormone melatonin (used to treat insomnia and jet lag). New drinks carry names such as Mary Jane's Relaxing Soda, Slow Cow, Ex Chill and VIB (ie, vacation in a soda). There are neither age restrictions on the sale of kava-based products nor any known negative effects associated with their consumption; most probably because of the lack of research. Wahlgren¹ cites health information from WebMD that side effects of valerian root may include headache, upset stomach, abnormal heartbeat, and insomnia. Melatonin may cause lower body temperature and affect blood flow. It remains to be seen whether this new lifestyle trend will have the success of EDs.

It has been reported that online drug use information is associated with increasing general curiosity about drugs and intent to use drugs.³⁵ Therefore, it is likely that as the word on these new beverages spreads by mouth and Internet, more youth will experiment and perhaps continue to use Anti EDs.

SUMMARY AND CONCLUSIONS

The consumption of EDs does not seem to carry adverse effects that are any different from drinking similar amounts of other caffeinated beverages. However, frequent consumption of EDs may serve as a useful screening indicator to identify students at risk for substance use and other problem behaviors.

Communities, state, and federal governments should educate, monitor, and collect data on consumption and adverse effects, and look for legal actions to control the potential harm by excessive use of EDs and of any consumption of AEDs. Special emphasis on prevention-intervention is necessary to protect the impressionable minds of adolescents who are exposed to manipulating advertisements that encourage the consumption of EDs and AEDs. (For a detailed recommendation on legal action please refer to a review by Simon and Mosher.³¹)

The qualitative and quantitative effects resulting from excessive and chronic consumption of EDs, as well as from potential interactions with medications and the dynamic innovation and availability of new street drugs, are not fully known. For example, anecdotal information has been provided regarding a combination of EDs and Adderall, a prescription drug for attention deficit disorder that is popular on college campuses. Adderall improves focus and the EDs maintain wakefulness.⁶ The label on the drink Endo-Rush carries a warning against its consumption by individuals less than 18 years of age, and those with depression, high blood pressure, or who are pregnant. Therefore, the potential for adverse effects from ED/AED use and drug interaction should always be considered until more empirical data are

available.³⁶ This precaution may be particularly important in youths with psychiatric disorders (see the article by Bukstein and Horner elsewhere in this issue for further exploration of this topic).^{37,38}

The debate about taxing sugar-sweetened beverages to combat youth obesity³⁹ may serve as a platform to consider taxing EDs, particularly for youth. Such an approach might improve prevention of adverse effects by forcing the manufacturers of these drinks to place warning labels and provide age limit and consumption guidelines.

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